Lithium emission spectra excited in the 10–25 nm region by electron-atom collisions

V. S. Bukstich, I. P. Zapesochnyĭ, and V. V. Samsonov

Uzhgorod State University

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We investigate, for the first time, the hard radiation produced when electrons from the *K* shell of the lithium atoms are excited by electron impact. We measured the energy dependences of the efficiency of excitation of spectral lines $\lambda = 19.9$ nm ($1s^2\ ^1S - 1s2p\ ^1P^0$) and $\lambda = 17.8$ nm ($1s^2\ ^1S - 1s3p\ ^1(P^0)$ of the singly-charged lithium ion, and also of one line $\lambda = 13.5$ nm ($1s\ ^2S - 2p\ ^2P$) of the doubly charged lithium ion.

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Investigations of the electromagnetic radiation of free atoms produced when electrons are knocked out from their internal shells have been attracting increasing interest of late. These investigations were made possible by the use of the technique of intersecting electrons and atom beams under high-vacuum conditions and spectral apparatus for the vacuum ultraviolet and soft x-ray regions of the spectrum.

We report here the results of an investigation of the emission of ultrasoft x-ray spectra of lithium, excited by an electron beam. To this end, an experimental setup was developed, including a dismountable high-vacuum metallic chamber with intersecting electron and atom beams, a specially constructed vacuum monochromator for glancing incidence of the rays (with a constant deflection angle 164°), designed for the spectral region from 4 to 30 nm, and the appropriate detection apparatus.

Figure 1 shows the lithium emission spectrum recorded at different energies of the exciting electrons. It is seen that it consists of four spectral lines. Three of the observed lines can be identified without particular difficulty with spectral transitions in the singly charged ($\lambda = 17.8$ and 19.9 nm) and doubly charged ($\lambda = 13.5$ nm) lithium ions, while the fourth line has not yet been uniquely identified. An analysis of the published data makes it only possible to assume that the line is due either to excitation of the lithium molecule or to radiative decay of the auto-ionization states of the atoms.

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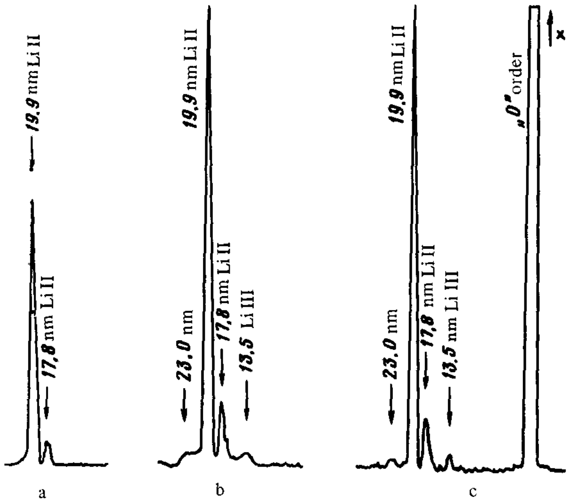

FIG. 1. Emission spectra of lithium excited by electron beams of energy 100 eV (a), 300 eV (b), and 500 eV (c).

As expected, the intensity of the first term of the resonance series of the singly-charged ion greatly exceeds the intensity of the second term. The intensity of the resonance line of doubly-charged ions is likewise relatively small. Thus, for example, at an electron energy 500 eV, the ratio of the intensities of the $\lambda = 19.9$, 17.8, and 13.5 nm lines is respectively 22 : 3 : 1. We note that this

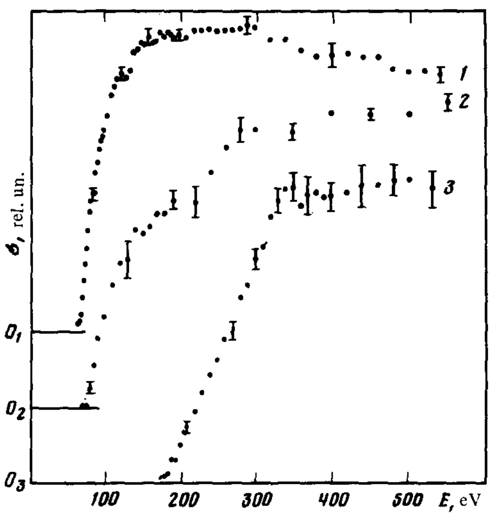

FIG. 2. Energy dependences of the excitation efficiency of the spectral transitions: 1 – $\lambda = 19.9$ nm ($1s^2\,{}^1S = 1s2p\,{}^1P^0$) Li II; 2 – $\lambda = 17.8$ nm ($1s^2\,{}^1S - 1s3p\,{}^1P^0$) Li II; 3 – $\lambda = 13.5$ nm ($1s^2S - 2p^2P$) Li III.

ratio does not take into account the wavelength dependence of the reflection efficiencies of the radiation by the focusing mirror and by the diffraction grating, nor the quantum yield of the radiation detector.

In addition to investigating the spectra of different bombarding-electron energies, we measured the detailed energy dependences of the excitation cross sections of the three identified spectral transitions shown in Fig. 2. The experimental points on the obtained plots for certain electron-energy values are marked with the 90% confidence interval of the relative error. All three curves are characterized by a rather abrupt increase of the effectiveness past the excitation threshold and by a negligible change at high energies.

Owing to the still unsurmounted difficulties of absolute calibration of the spectral instrument in the region below 30 nm and to the absence of any theoretical calculations of simultaneous ionization with excitation of the lithium atom by electron impact, we were unable to determine the absolute cross sections for the excitation of the investigated spectral lines.